

MEDICAGO RIGIDULA AND M. TRUNCATULA (FABACEAE):
NEW TO THE CALIFORNIA FLORA

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ABSTRACT

Medicago rigidula and *M. truncatula* are reported for the first time for California. These species have likely become established from rangeland, forage and cover crops grown over the past century. They can be confused with the relatively common *M. polymorpha*, and are probably more widespread than current records indicate.

KEY WORDS: biological invasions, grasslands, *Medicago rigidula*, *Medicago truncatula*, medics, nonnative plants

RESUMEN

Medicago rigidula y *M. truncatula* se reportan por primera vez en California. Probablemente estas especies se han establecido a través de los pastizales de forraje y los cultivos de cobertura sembrados durante el siglo pasado. *Medicago rigidula* y *M. truncatula* pueden ser confundidas con la especie relativamente común *M. polymorpha*, y probablemente están más generalizadas que lo indicado por los registros actuales.

Annual species of *Medicago*, commonly known as medics, are indigenous to the Mediterranean region, and some of these have become established in temperate and Mediterranean-type climate regions around the world (Heyn 1963; Piano & Francis 1992). In this paper, we provide the first documented records of *Medicago rigidula* (L.) All. and *M. truncatula* Gaertn. for California.

Medicago rigidula (Tifton medic, Tifton burclover, Tifton bur medic, rigid medic) and *M. truncatula* (barrel medic, barrel clover) have not been reported previously in major publications addressing nonnative species in California (Isely 1993; Bossard et al. 2000; Hrusa et al. 2002; Bossard & Randall 2007; DiTomaso & Healy 2007; Jepson Flora Project 2008; USDA 2008a, b). They have also not been included in treatments of the Fabaceae in county floras or in recent local floristic studies covering coastal southern California (Boyd 2001; Schneider-Ljubenkova & Ross 2001; Bowler & Bramlet 2002; Wishner 2002; Bowler & Elvin 2003; Pyke et al. 2003; Roberts et al. 2004; Rebman & Simpson 2006; Clarke et al. 2007; Roberts & Bramlet 2007; Roberts et al. 2007; Roberts 2008).

Voucher specimens:

Medicago rigidula (Fabaceae, Trifolieae, Trigonellinae), **U.S.A. CALIFORNIA. Orange Co.:** City of San Juan Capistrano, San Juan Creek Rd. at San Juan Creek Circle, UTM (NAD 83) 11S 0439671E 3706917N, elev. ca. 24 m, uncommon in annual grassland, 18 Mar 2007, Riefner 07-150 (RSA); City of Laguna Niguel, Laguna Niguel Regional Park, general vicinity of La Paz Rd. at Aliso Creek, UTM (NAD 83) 11S 0434480E 3712053N, elev. ca. 70 m, uncommon, disturbed roadside, 1 Apr 2007, Riefner 07-165 (DAO, RSA); City of San Juan Capistrano, San Juan Creek area, ca. 0.2 mi W of intersection of Paseo Tirador and Calle Arroyo St., UTM (NAD 83) 11S 0439010E 3706660N, elev. ca. 31 m, uncommon in open field, 1 May 2008, Riefner 08-73 (DAO, RSA); Ladera Ranch, Cecil Pasture at Jerome Rd., UTM (NAD 83) 11S 0439962E 3713383N, elev. ca. 157 m, uncommon along Bluff Top Trail in annual grassland, 12 May 2008, Riefner 08-75 (DAO); City of San Juan Capistrano, 0.2 mi E of Antonio Pkwy. on Hwy. 74 (Ortega Hwy.), UTM (NAD 83) 11S 0442824E 3709137N, elev. ca. 88 m, uncommon in annual grassland and disturbed sage scrub, 19 May 2008, Riefner 08-99 (RSA); unincorporated land located between the Cities of Lake Forest and Rancho Santa Margarita, El Toro Rd. near Meadow Ridge Dr., UTM (NAD 83) 11S 0442282E 3725738N, elev. ca. 362 m, rare along fire break with ruderal vegetation, 22 May 2008, Riefner 08-120 (RSA).

Medicago truncatula (Fabaceae, Trifolieae, Trigonellinae), **U.S.A. CALIFORNIA Orange Co.:** City of Laguna Niguel, Laguna Niguel Regional Park, general vicinity of La Paz Rd. at Aliso Creek, UTM (NAD 83) 11S 0434480E 3712053N, elev. ca. 70 m, uncommon in *Atriplex* scrub, 1 Apr 2007, Riefner 07-166 (DAO, RSA); City of Laguna Niguel, Laguna Niguel Regional Park, general vicinity of La Paz Rd. at Aliso Creek, UTM (NAD 83) 11S 0434316E 3712082N, elev. ca. 63 m, uncommon in *Distichlis* grassland (plant with conspicuous,

reddish, diamond-shaped mark in center of each leaflet lamina), 1 Apr 2007, *Riefner 07-168* (DAO); City of Orange, SW portion of Irvine Regional Park, Irvine Park Rd., UTM (NAD 83) 11S 0431403E 373509N, elev. ca. 188 m, uncommon in disturbed and ruderal habitats, 12 Apr 2007, *Riefner 07-178* (DAO, RSA); City of Rancho Santa Margarita, Tijeras Canyon, N ca. 0.5 mi from Meandering Trails Rd. on Antonio Pkwy., UTM (NAD 83) 11S 0442289E 3718077N, elev. ca. 221 m, uncommon in annual grassland, 24 March 2008, *Riefner 08-64* (RSA); City of San Juan Capistrano, 0.2 mi E of Antonio Pkwy. on Hwy. 74 (Ortega Hwy.), UTM (NAD 83) 11S 0442824E 3709137N, elev. ca. 88 m, uncommon, roadside and annual grassland, 19 May 2008, *Riefner 08-92* (DAO, RSA).

Medicago rigidula sensu lato is native to Eurasia and North Africa (Small & Jomphe 1989; Small et al. 1990). The European and African populations have been segregated as *M. rigiduloides* E. Small, based particularly on pollen morphology and fruit characters (Small 1990; Small et al. 1990). Additional studies confirming separation of these taxa are needed (Heft & Groose 1996), so we have not attempted to identify the California collections with respect to these groups. *Medicago truncatula* is also indigenous to Eurasia and North Africa (Small & Jomphe 1989; Small et al. 1990; Small et al. 1991). With the exception of *M. polymorpha* L., it is the most common weedy annual *Medicago* in the Old World (Small & Jomphe 1989).

Medicago rigidula and *M. truncatula* grow on a variety of soils, ranging in texture from sandy loams to clay, and the former is adapted to rocky soils; both species are best adapted to neutral to somewhat alkaline (pH 6 to 9) conditions (Small & Jomphe 1989; Nair et al. 2006; Frame 2008). The annual medics are not cold hardy and will die after a killing frost (Quinlivan et al. 1986). However, *M. rigidula* is relatively cold tolerant (Walsh et al. 2001; Small & Jomphe 1989; Krall et al. 1996). Although not widely recognized as a halophyte, *M. truncatula* performed very well in an experimental study of cover crops suitable for saline soils of California's Great Central Valley (Mitchell 1996).

Medicago species are among the legumes that are highly selective of rhizobial bacteria, which have important nitrogen fixing properties (Allen & Allen 1981). The annual species of *Medicago* are highly adapted to a wide range of environments and to new locations (Crawford et al. 1989). Accordingly, many annual medics now play an important agronomic role in dryland farming around the world (Walsh et al. 2001). The annual medics comprise the principal legume component of pasture lands on more than 20 million ha in Southern Australia where they are utilized as self-seeding annuals to improve soil structure, increase soil nitrogen, and provide forage for livestock (Cocks et al. 1980; Crawford et al. 1989; Squires & Tow 1991). *Medicago truncatula* is a highly valued and widely cultivated species in Australia and other Mediterranean climate regions around the world (Crawford et al. 1989; Walsh et al. 2001; Nair et al. 2006). There are more cultivars of *M. truncatula* than of any other *Medicago* except *M. sativa* L. (alfalfa). *Medicago truncatula* is also being developed as a model legume plant in both classical and molecular genetic studies to elucidate the functions of its genes (e.g., bacterial and fungal symbiosis, stress resistance, and plant architecture) and to exploit its genome (e.g., improved seed quality and production of specific secondary metabolites); for recent reviews see Thoquet et al. (2002) and Watson et al. (2003). By contrast, *M. rigidula* has attracted relatively limited interest as an agricultural crop, and there are few cultivars.

In coastal southern California, ranchers have long prized burr clover (*M. polymorpha*) as valuable forage (U.S. Coast & Geodetic Survey 1891). Several other annual medics, including *M. arabica* (L.) Huds., *M. lupulina* L., *M. rigidula*, *M. scutellata* Mill., *M. truncatula*, and *M. turbinata* (L.) All. were tested in row nurseries or broadcast plots in order to improve forage on California rangelands, including four sites in Orange County, southern California (Jones & Love 1945). These species did not perform well during the early field tests, and were not recommended for use on rangelands in the South Coast region (Jones & Love 1945). However, following the successful breeding and development of numerous cultivars and experimental genotypes, many annual species of *Medicago*, including *M. rigidula* and *M. truncatula*, have been successfully re-evaluated for use and/or are currently utilized as cover crops or forage in the United States (Allen & Allen 1981; Zhu et al. 1996; Shrestha et al. 1998; Fisk et al. 2001; Walsh et al. 2001; Krall et al. 2007). In California, the annual medics are favored as cover crops in no-till orchards and vineyards, especially in the Great Central Valley (Miller et al. 1989; UC SAREP 2008). Despite their widespread use, *M. rigidula* and *M. truncatula* have been rarely reported growing outside of cultivation in the United States (Kartesz & Meacham 2005; Jepson Flora Project 2008; USDA 2008a, b).

There are several reasons why the annual medics should be expected as introduced weeds in California. All of the dozen or so cultivated medics are weeds in the Old World, and have the potential to be weedy elsewhere. The cultivars that are often grown experimentally or for their proven value in California are scarcely different from their wild progenitors. In addition, essentially wild plants are also often cultivated. Accordingly, the annual medics have not been weakened by domestication.

Also, the majority of the annual species of *Medicago* have spiny pods adapted to adherence to fur and feathers, which are easily distributed by wild animals, and also by humans (for example, in wool). Their seeds are well protected in indehiscent, spiny pods, and are long lived. A seed of *M. polymorpha* extracted from adobe brick from Mexico, estimated to be of the order of 200 years of age, successfully germinated (Spira & Wagner 1983). Therefore, it would not be surprising to find annual medics naturalized in California.

Southern Orange County supports ideal conditions that have facilitated the introduction and naturalization of annual medics, which include: a Mediterranean-type climate; widespread neutral to alkaline sandy loam to clay soils; extensive historic ranchos supporting cattle grazing, dryland row crops, orchards, and equestrian uses; and expanding residential/commercial land development that has split up the historic ranchos, increased disturbance, and facilitated invasions of new weed species in the region (Wachtell 1978; Hallan-Gibson et al. 2005; Orange County Historical Society 2005; Riefner & Boyd 2007). Notably, access to historic grazing habitats in southern Orange County is now possible owing to lands dedicated to open space and conservation, most of which have been poorly studied (Roberts & Bramlet 2007).

Some medic cultivars are characterized by single, reddish, adaxial leaflet marks (Nair et al. 2006), although this phenomenon is relatively rare among most wild medic species. Some of the plants collected in Orange County (Riefner 07-168, DAO) have such marks, which may reflect origin from agricultural cultivars. Many of the medic cultivars have been selected for resistance to aphids and root-lesion nematodes, and adaptations to specific soil textures (Nair et al. 2006). Early introductions of *M. rigidula* and *M. truncatula* failed to establish, perhaps because of lack of suitable adaptations, but continued releases of cultivated strains may have led to hybridization and the production of invigorated populations, aiding naturalization in southern California. The introduction of cultivars has been hypothesized to contribute new genetic diversity that could enhance or aid the establishment of nonnative plants (Cox 2004).

In Eurasia, it is extremely common for several species of annual *Medicago* to grow together as weeds. In Orange County, *M. rigidula* and *M. truncatula* are closely associated with *M. polymorpha*, which is the most commonly collected medic in southern California and the most likely to be confused with either *M. rigidula* or *M. truncatula*. *Medicago rigidula* and *M. truncatula* are members of section *Spirocarpos* Ser. subsection *Pachyspirae* (Urb.) Heyn, which is characterized by pods that at maturity are extremely hard, and have alveolar (appearing spongy) tissue on the coil faces (and at the base of spines) that often obscures the coil venation (Small & Jomphe 1989). *Medicago rigidula* pods are usually covered with velvety-glandular hairs (observable in young pods), are discoid, cylindrical, ovoid or spherical in shape, often have evident inter-coil gaps on mature pods, and have radial veins that are strongly curved with limited anastomosing (Heyn 1963; Small & Jomphe 1989; Bena et al. 1998). *Medicago truncatula* has cylindrical pods, usually with a few simple trichomes (often on the spines), long curved spines that frequently point towards the ends of the pod, and weakly to moderately curving radial veins on the coil faces, with limited anastomosing (Heyn 1963; Small & Jomphe 1989; Bena et al. 1998). Occasionally, plants of *M. truncatula* and *M. rigidula* have pods without spines, and both species have moderately pubescent herbage.

Medicago polymorpha, of section *Spirocarpos* (= subsection *Leptospirae* (Urb.) Heyn), is generally glabrous to lightly hispid, and the pods, spiny or rarely merely with tubercles, generally have conspicuous reticulate venation on the coil faces. However, *M. polymorpha* frequently mimics species of *Pachyspirae* in developing very hard pods with proliferating tissue on the fruit coil faces, making identification difficult (Small & Jomphe 1989). This mimicry does not occur in young pods, which should be examined for positive identification. Typical pods of *M. rigidula*, *M. truncatula*, and *M. polymorpha*, and venation on coil faces are depicted in Figure 1.

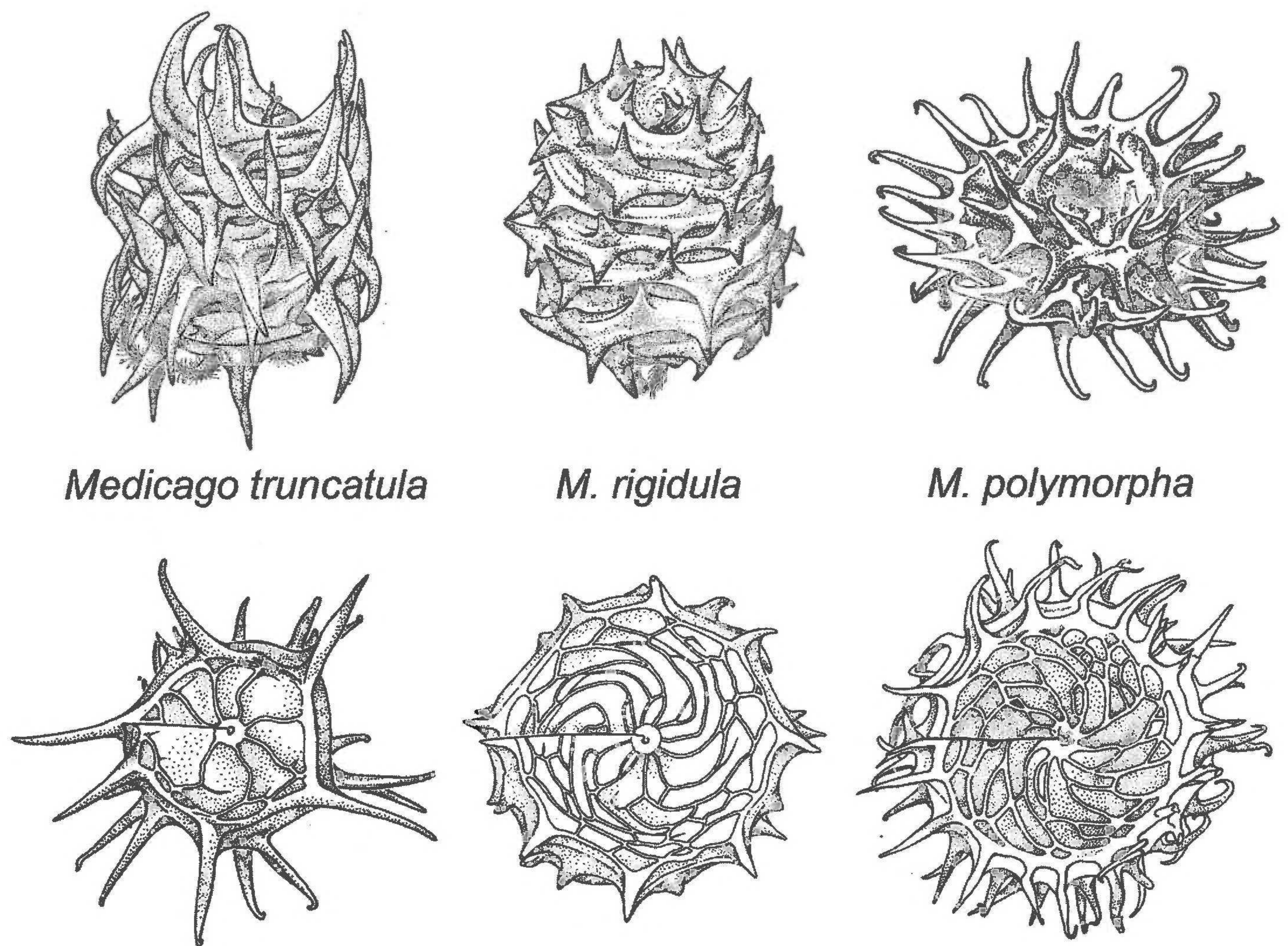
*Medicago truncatula**M. rigidula**M. polymorpha*

FIG. 1. Typical fruits (top row) and coil faces (bottom row) of *Medicago* species discussed in text. *Medicago truncatula* characteristically has a few simple hairs on the fruits (often on the spines) while *M. rigidula* pods are typically covered with a velvety surface of gland-tipped hairs; venation of the coil faces of these species is obscured by a sponge-like tissue at maturity. Occasionally the venation of pods of *M. polymorpha* is similarly obscured. Length and orientation of spines are variable in these taxa. (All fruits shown are about 1 cm wide. Illustrator: Lucy Yuzyk)

Given the difficulty of discriminating *M. rigidula* and *M. truncatula* from the widespread *M. polymorpha*, it may be that the species reported here as new to California could be established in other agricultural regions of the State, including the Great Central Valley and the Imperial Valley, where there are extensive, suitable habitats.

Note.—After the manuscript was accepted for publication, we identified the two voucher specimens of “*Medicago muricata* All.” cited in Dean et al. (2008) (collections made by G. Butterworth in 2005 from San Luis Obispo Co.) as *M. truncatula* Gaertn.

ACKNOWLEDGMENTS

We greatly appreciate the efforts of Harvey Brenneise and Irene Holiman (Library of Rancho Santa Ana Botanic Garden) for assistance with document retrieval. George W. Cox (San Diego State University) and an anonymous reviewer provided helpful comments that greatly improved the manuscript. We also thank Fred Hrusa (California Department of Food and Agriculture, CDA) for a loan of specimens.

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